Analysis of Counterfeit Currency Detection Techniques for Classification Model

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***Abstract* - Counterfeit currency is one of the threats which creates vice to nation's economy and hence impacts the growth worldwide. Producing forge currency or fabricating fake features in the currency considered to be a crime. Currency crime comes under the criminal law and known to be as Economical crime. Over the past few years many researchers have proposed various techniques to identify and detect forged currency. The serious problem has been come up with variety of solutions in terms of hardware related techniques, Image processing and machine learning methods. Advancements in printing and scanning technology, trading of material are some of the problems in germinating counterfeit currency. The study presents various fake currency detection techniques proposed by various researchers. The review highlighted the methodology implemented on particular characteristics feature with success rate of each method to detect counterfeited currency. Moreover, the study includes the analysis of widely acceptable statistical classification technique for currency authentication. The comparative analysis of Logistic Regression and Linear Discriminant Analysis (LDA) was performed to realize the better model for currency authentication. It has been found that classification Model using Logistic regression shows better accuracy of 99% then LDA. The study will benefit the reader in identifying most feasible technique to be implemented based on the accuracy rate.**

Keywords— fake currency, classification model, statitical techniques, machine learning, Logistic regression, logit regression, Linear Discriminant Analysis, LDA, feature extraction, detection techniques, counterfeiting, economical crime, currency features, image processing, INR, indian rupees, bank notes

I. ORGANIZATION OF PAPER

The paper is divided into five sections including organization of paper. Section I deals with Introduction about fake currency and different methodologies to handle counterfeit currency. Section II deals with introduction to the concept of counterfeit currency and section III illustrates the various types of methods for detection and identification of counterfeit currency. Next section discusses the past studies conducted in this area and various techniques proposed by them. The study is then concluded with establishing the study by contributing the future aspects that can be incorporated to determine optimal solution of the problem.

II. INTRODUCTION

Counterfeiting is a deliberated replication of genuine currency. It is performed to deceive the receiver into believing that the entity received is genuine. The growth of counterfeited currency is becoming a great threat to worldwide by impacting each country thoroughly [2]. As per National Crime Records Bureau (NCRB), India, Counterfeiting offence is one of the Indian Panel Code (IPC) crimes relating to Economic crimes (NCRB Compendium 2015-16). IPC Economic crimes accounted for 5.1% of the total IPC crimes (NCRB Compendium 2015-16) [1]. [3] discussed in their study that reproducing any currency with an illegal means is considered to be counterfeiting. It is also mentioned in the paper that counterfeiting as a profession is as old as currency in itself and it is known to be as world's second oldest profession. Increase in counterfeit currency is due to technological advancement and various other factors [4]. One of the nocuous effects of counterfeit money is that it directly hits the value of real money by causing reduction in value [5]. The rate of counterfeiting is widely increasing due to fleeting acquisition of technology. The reason of swift adoption is cost, availability and efficiency of technological equipment [6]. From past many years the race is going on between the counterfeiters and the banks. To resolve the issue various researchers came across with variety of techniques and proposed solutions from the area of Machine learning and Image processing for this serious issue.

III. CURRENCY DETECTION TECHNIQUES

There are many currency detection techniques which have been proposed by various researchers in the field of machine learning and Image processing.

Machine learning techniques: It can be divided into supervised, unsupervised learning or amalgamation of both learning techniques. It totally depends upon the type of the data collection that which type of technique must be implemented to get good results [16]. Supervised machine learning techniques are those where value of output variable is predicted with the help of input variable. It is known to be supervised learning because it deals with training dataset and testing dataset. These types of technique are majorly grouped into Regression and classification. Regression is implemented when the problem has output variable in terms of real value while classification is used when output variable is having a category. Some of the supervised machines learning technique are Linear regression, multiple regression, logistic regression, linear discriminant analysis, support vector machine, decision tree, neural network, naïve bayes, k-nearest neighbor [12]. Unlike supervised learning technique, unsupervised machine learning technique is the one that contains values for input data but having no corresponding output variable. Unsupervised learning aims to design the repressed structure based on the different input variable values. Unsupervised learning problems are majorly grouped into clustering and association. Clustering technique is used where problem refers to the identification of certain groups based on their similar characterstics. Association technique is implemented where problem refers to identification of certain rule that can define substantial segment of data. Some of the unsupervised learning techniques are Apriori, k-means, clustering, mixture models, hierarchical clustering, anamoly detection, autoencoders, deep belief nets, hebbian learning, generative adversarial networks, principal compenent analysis, Independent component analysis, non-negative factorization. Singular value composition, expectation-maximization and methods of moments [20].

Image processing: Another widely used area which have been used for currency detection and identification is Image processing. Image processing is a method to perform image operations to extract features of image or to get enhanced quality image. The image processing technique majorly deals with Edge detection and feature extraction. Image processing includes following steps starting with acquisition of image, image enhancement and improvement, segmentation, feature extraction and then using the extracted part for further analysis and knowledge base. Two major steps where various techniques can be applied are edge detection and feature extraction. Edge detection comes under segmentation and it is performed to extract the object of interest from the image. Segmentation technique that can be applied over the image includes Roberts edge detection, Sobel edge detection, Prewitt edge detection, kirsch edge detection, Robinson edge detection, Marr-Hildreth, log edge detection, canny edge detection [9]. Feature extraction is performed after preprocessing and it is a part of pattern recognition. Feature extraction is generally divided into two stages feature selection and its classification. It is important to construct any pattern and then classify it for extraction of relevant information. Various feature extraction techniques can be grouped into three methods: statistical feature extraction methods, global transformation & series expansion methods and geometrical & topological methods. Each group includes various techniques such as zoning, charaterstic loci, fourier transaform, rapid transform, moments, Karhunen Loeve expansion, strokes, chain codes and many more to implement feature extraction [11].

IV. RELATED STUDY

Currency counterfeiting is itself a threat to any nation's economy and hugely affects the demographics. Counterfeit currency can be detected by passing Ultra violet light and also through polarization of light. Currency will be proved to be forged if results from both detections is positive[2]. [3] has discussed the methodology to detect fake currency through counterfeit detection pen and MATLAB. The pen would enable the individual to detect some of the features of currency i.e. watermark, optically variable ink, security thread, latent image etc. [3]. Various fake currency detection techniques based on security features have been discussed by [4]. The study revealed various existing work for determining best and feasible solution for counterfeit currency detection but it also established that 100% accurate and reliable technique still need to be developed for counterfeit currency detection [6]. To help the individual in checking the originality of currency, an android app has been developed for detection [7]. Currency detection based on extracting a particular feature i.e. security thread using neural network and pattern recognition is performed and discussed in [8]. Table I discusses other various work which have been performed and implemented with their accuracy rate for currency detection.

TABLE I. TECHNIQUES FOR DETECTION OF COUNTERFEIT CURRENCY.

Authors	Year	Technique	Accuracy /success rate	Applied on
Abba Almu and Aminu Bui Muhammad	2017	Application implemented using MS Access and Visual Basic	77%	Algorithm based on features comparison of Nigerian currency Naira 100, 200, 500, 1000
Jayant Kumar Nayak et. al.	2015	Chan-Vese segmentation, ROI, backpropagation algorithm	98% Average accuracy for both types of notes (average soiled and very soiled)	ROI segmented images of Indian currency denomination values 5, 10, 20, 50, 100, 500
Snigdha Kamal et. al.	2015	SURF Descriptor and SVM Classifier	97%	Feature extraction and recognition based on Central Numeral, Ashoka emblem, Identification mark and color band of Indian rupee 500

Lamsal S, Shakya A	2015	Image classification based on colour and texture using Skew, mean, standard deviation, entropy and correlation value	95%	Color descriptor and texture parameter of Nepal currency 500
Ballado et. al.	2015	Canny Edge detection and proposed to inbuild OVD patch	100%	GUI based program for Philippine currency Peso 500, 1000
Vishnu R & Omman B	2014	Pattern matching on similarity of feature extracted, dominant color and shape detection method.	97%	6 security features considered; Color, shape, Centre, Ashoka emblem, RBI seal, Signature i.e. 50, 100, 500, 1000 of Indian currency
Singh et. al.	2014	Visual Bag of Words, feature detection and extraction using SIFT, SURF and ORB-FREAK	96%	Currency recognition application specially designed for visually impaired for Indian denomination value 10, 20, 50, 100, 500, and 1000. Excluded color, text and size of denomination.
Ankush Roy et.al.	2014	SVM and ANN	100%	Based on security thread, Ink, printing technique and artwork of Indian currency
Abbas Yaseri and Sayed Mahmoud Anisheh	2013	Wiener filter Fourier Mellin transform SVM Classifier	98%	Different quantization levels and segmentation of the paper currency dataset of 150 banknotes of 101 different denominations from 23 countries
Subra Mukherjee et.al.	2012	defining window size of an image,segmentation on the basis of Identification mark, fourier descriptor for feature extraction	97%	Unique identification mark on different denominations of Indian currency i.e. Rupee 20,50,100,500,1000
F. M. Hasanuzzaman et. al.	2012	Component based recognition using SURF	100%	Reference region of 14 ground truth images of seven categories bill; US Dollar 1, 2, 5, 10, 20, 50, 100
Kalyan Kumar Debnath et.al.	2010	Negatively correlated Ensemble Neural Network	100%	Gray scale image of 7 different types of Bangladeshi taka 2,5,10,20,50,100, 500 and 1000
F. Grijalva et. al.	2010	Eigen faces based on Principal Component Analysis	99%	Currency recognition application specially designed for visually impaired for all denomination value of US Dollar

Hamid Hassanpour et.al.	2009	Hidden Markov Model	98%	Size, color histogram and texture based features of Iranian Rial

V. ANALYSIS OF STASTICAL CLASSIFICATION TECHNIQUES

From number of past studies it was found that Image processing and pattern recognition are the prominent base area for currency authentication. Past researchers mainly used the image processing and pattern recognition techniques like Canny Edge detection, Sobel operator, SIFT etc. Other techniques which were also used to authenticate the currency, was along with machine learning techniques such as Fourier descriptor, ANN, Neural network based on ROI & HSV, Support Vector Machine with SURF descriptor etc. On closer view to all these techniques it was found that to design a classification model for data authentication, techniques can be divided into three dimensions: Image processing, machine learning and Statistical techniques. Classification models using Statistical techniques are more based on mathematical notions. Additionally the extensive use of above mentioned techniques shows that statistical techniques like Regression analysis and LDA can also be used to design of classification model for identification of a currency as Genuine or fake. Hence in order to analyse the performance of these techniques average accuracy of the models have been derived and compared. These two techniques have been taken into consideration as a part of Statistical techniques because target variable in the dataset is categorical in nature.

Dataset description: The dataset used to identify the accuracy of the statistical techniques is taken from UCI machine learning repository. The possessor of dataset is Volker Lohweg and it is donated by the Helene Darksen. The dataset is having 1372 instances in proportion of 55:45 i.e. 55% genuine currency instances and 45% forged currency instances. The independent attributes are Variance, skewness, kurtosis and entropy. The target variable of the dataset is class, in which genuine banknotes is identified through the value 0 and 1 as fake banknote. These attributes were derived using wavelet transform on Euro banknotes.

To find the average accuracy of statistical techniques the dataset was divided into training and testing using random function i.e. Bernoulli's function with different proportion as 70:30 and 60:40. The data was 20 times simulated for each of the technique. Each time the dataset was randomly distributed as training and testing. To simulate the dataset IBM SPSS 20 software was used. Following table shows the average accuracy of the classification model and also results of each simulation for both the techniques are presented in the table.

TABLE II. SIMULATION OF LOGISTIC REGRESSION.

Simulation	Training (model fit %)	Testing (model validation %)
1	98.8	99
2	99.4	98.6
3	99.4	98.3
4	98.7	99.2
5	98.6	99.3
6	99.4	99.3
7	99.3	98.3
8	98.9	99.8
9	98.7	99.3
10	99.1	99.3
11	98.8	99.1
12	99.4	98.8
13	99.3	98.6
14	98.7	99.3
15	99.0	99.5
16	99.3	99.3
17	99.2	98.9
18	98.8	99.8
19	98.7	99.4
20	99.0	99.3
Average Accuracy	99.0	99.2

TABLE III. SIMULATION OF LINEAR DISCRIMINANT ANALYSIS.

Simulation	Training	Testing
1	98.1	98.7
2	98.2	97.9
3	98.4	97.4
4	98.4	98.0
5	98.2	98.4
6	98.2	98.3
7	98.5	98.8
8	98.1	98.6
9	98.4	97.8
10	98.1	98.5
11	98.1	97.9
12	98.	97.3
13	98.3	98.2
14	98.0	98.0
15	98.7	97.7
16	98.2	98.0
17	98.5	97.9
18	98.1	98.5
19	98.5	97.9
20	98.9	97.2
Average Accuracy	98.3	98.1

From table II and table III it is found that training and testing models are very consistent to each other and hence provide reliable results for both techniques. The model is validated as estimated percentage for training and testing model are equivalent. When two techniques were compared for best classification model in terms of accuracy, it is found that Logistic regression model is more preferable over Linear Discriminant Analysis, with average accuracy of 99% for training model and 99.2% for testing or validation model.

VI. CONCLUSION AND FUTURESCOPE

It is a ever raising issue for research community to identify and detect the counterfeit currency with best possible solution. Hence, detailed study about various techniques based on particular currency denomination has been conducted. It is found that techniques developed and implemented majorly falls under the area of image processing, pattern recognition and machine learning. Few of the models and detection techniques have simulated the results for no. of runs to get better results for all permutations. The gap lies in terms of using statistical techniques like Regression analysis, Linear Discriminant Analysis where models can be developed to predict the new data for the chance of being genuine or fake. This paper provides quick overview about various methodologies and their respective accuracy rate for detection of originality of currency. The effort is also made to analyze and compare the prediction and classification statistical technique i.e. logistic regression and LDA. Simulation results shows that Logistic Regression gives 99% of accuracy for designing a classification model. Hence models can be designed and developed using statistical techniques for better performance and accuracy.

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